Imported Seabass as a Source of Mercury Exposure: A Wisconsin Case Study

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The Wisconsin Division of Health investigated mercury exposure in a 40-year-old man, his 42-year-old wife, and their 2.5-year-old son. At the time of our investigation, these individuals had blood mercury levels ranging from 37 to 58 µg/L (normal <5 µg/L) and hair samples from the adults contained 10–12 µg mercury/g dry weight. A personal interview and home inspection failed to identify any occupational or household sources of mercury exposure. The family's diet included three to four fish meals per week. The fish was purchased from a local market and included Lake Superior whitefish, Lake Superior trout, farm-raised trout and salmon, and imported seabass. Analysis of these fish found that only one species, the imported seabass, contained significant mercury levels. Two samples of the seabass obtained from the vendor on different days contained mercury concentrations of 0.5 and 0.7 mg/kg. Based on consumption estimates, the average daily mercury intakes for these individuals ranged from 0.5 to 0.8 µg/kg body weight. Six months after the family stopped consuming the seabass, blood mercury levels in this man and woman were 5 and 3 µg/L, respectively. Analysis of sequential blood samples confirmed that mercury elimination followed first-order kinetics with a half-life of approximately 60 days. *Key words*: dietary exposures, half-life, mercury, seabass. *Environ Health Perspect* 103:604–606 (1995)

The hazards posed by methylmercury-contaminated seafood were first recognized in 1955 when a poisoning outbreak occurred in Minamata, Japan. In that incident, severe brain damage was described in 22 infants whose mothers had ingested contaminated fish during pregnancy (*1*). Similar prenatal effects were observed in the aftermath of two poisoning outbreaks that occurred in Iraq (*2*), confirming the sensitivity of the developing central nervous system to the toxic effects of organic mercury. The symptoms of methylmercury poisoning in adults include paresthesia; impaired peripheral vision, hearing, taste, and smell; slurred speech; unsteadiness of gait and limbs movements; muscle weakness; irritability; memory loss; depression; and sleep disturbances (*3*). Prenatal and infantile exposures can cause permanent brain damage resulting in mental retardation, blindness, inability to walk, retention of primitive reflexes, and lack of coordination (*1*).

Current regulations administered by the U.S. Food and Drug Administration limit the methylmercury content in commercially marketed fish to 1.0 mg/kg (1.0 ppm) (*4*). This guideline is based on an acceptable daily intake (ADI) for methylmercury (as mercury) of 30 µg and assumes a maximum fish ingestion rate of 30 g/day—the equivalent of one 7–8 oz serving per week—by a 70-kg adult. Higher ingestion rates, lower body weights, higher mercury levels in the fish, or a combination of these factors would result in exceeding the acceptable daily intake for methylmercury and could pose a health risk, especially in cases involving prenatal exposure.

During 1994, the Wisconsin Bureau of Public Health investigated mercury exposure in a 40-year-old man, his 42-year-old wife, and their 2.5-year-old son. These individuals were found to have elevated blood and hair mercury levels after they consumed three to four fish meals per week over a period of 8 to 9 months. Our investigation included a home inspection, personal interviews, assessment of dietary and occupational exposures to mercury, blood and hair analyses, and analysis of mercury levels in five species of fish that were regularly consumed by this family.

Methods

The personal, dietary, and residential information included in this report were obtained by an interview and home inspection. Analysis of mercury levels in blood and unskinned fish fillets was performed by the Wisconsin State Laboratory of Hygiene according to an adaptation of the cold vapor atomic absorption method developed by Chang et al. (*5,6*). The laboratory's limit of quantitation was 5 µg/L for blood analyses and 0.02 mg/kg for fish tissue. A 2.5-inch-long scalp segment of the woman's hair was analyzed by the Wisconsin Occupational Health Laboratory using nitric acid digestion followed by a flow-injection atomic absorption method adapted from NIOSH S199 and S342 (*7*). A scalp segment of the man's hair was analyzed by a private laboratory according to a similar protocol (method reference unavailable).

Case Findings

During March 1994, the Wisconsin Bureau of Public Health was contacted by a 40-year-old man who expressed concern about his family's exposure to mercury. He stated that a sample of his hair had been analyzed for toxic metals and found to have a high mercury content. He also said that he was experiencing sleep disturbances and had difficulty concentrating, and asked whether these symptoms might be due to mercury exposure. The caller was especially concerned about his 2.5-year-old son's exposure to mercury.

When asked about possible mercury exposure, the caller stated that his family regularly consumed three to four fish meals per week and asked whether the fish might contain unsafe mercury levels. He also wondered whether he should consider having his mercury-amalgam dental fillings removed. One week earlier, each member of this family had been seen by their physician. At that time, blood samples were collected for mercury analysis. It was recommended that the caller delay replacement of his dental amalgams until the results of the blood tests were available and an assessment of the family's mercury exposure was completed. A summary of the medical test results and personal information is shown in Table 1.

Other than the sleep and concentration difficulties reported by the caller, none of the family members exhibited clinical symptoms of mercury toxicity. Venous blood samples contained mercury levels that ranged from 37 to 58 µg/L (normal, <5 µg/L), confirming recent exposure to this metal. Based on these results, the family was advised to stop eating fish and other seafood products until the source of their mercury exposure could be determined.

A personal interview and home inspection failed to identify any significant occupational or household sources of mercury exposure. Both adults were attorneys and had offices in separate buildings. Their single-family home was located in a residential neighborhood of a medium-sized city. The home was constructed in 1976, was in good condition, and had not been repainted or remodeled since the family purchased it 3 years earlier. Neither adult could recall using elemental mercury or mercury-containing products in the home.

A 25-year-old woman who was employed by the family as a daycare provider spent approximately 40 hours per week in their home. She consumed a vegetarian diet which did not include fish or other seafood. A venous blood sample collected from her at the time of our investigation contained no detectable mercury (<5 µg/L).

All of the fish consumed by this family

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Received 17 January 1995; accepted 10 March 1995.

Table 1. Medical test results and personal data

	Man	Woman	Son
Age	40	42	2.5
Body weight kg (lbs)	57 (126)	52 (115)	13 (30)
Fish meals/week	3-4	3-4	3-4
Fish/meal (g)	227	150	75
Hair mercury (µg/g)	12	10	NA
Blood mercury (µg/L)			
Day 0	58	37	37
Day 15	45	24	NA
Day 70	24	14	NA
Day 200	5	3	NA
Hair Hg/blood Hg ratio	207	270	NA

NA, not available.

Table 2. Mercury content of fish

Type of fish	Mercury content (µg/g)
Lake Superior whitefish	< 0.02
Lake Superior trout	< 0.02
Farm-raised salmon	0.05
Farm-raised trout	0.05
Seabass	
Filet 1	0.5
Filet 2	0.7

Table 3. Estimated mercury content of seabass

	Blood mercury (µg/L)	Calculated mercury intake[a] (µg) Daily	Weekly	Seabass intake (g) Weekly	Estimated mercury content in seabass (µg/g)
Father	58	52	367	454	0.8
Mother	37	31	214	300	0.7
Child	37	9	63.7	150	0.4

[a]Calculated from blood mercury level as follows: 58 µg/L = daily mercury intake(0.059/4.0 L)(51.9 days/0.693); mercury intake = 52.4 µg/day or 367 µg/week.

was purchased from a local seafood market. The most frequently eaten fish were imported seabass (two meals/week), Lake Superior whitefish (one to two meals/month), Lake Superior trout (one to two meals/month), farm-raised trout (one to two meals/month) and farm-raised salmon (one to two meals/month). At each fish meal, about 454 g (1 lb) of fish was divided among the family members with the man, woman, and son consuming about 227, 150, and 75 g, respectively. One sample of each type of fish was obtained from the seafood market and tested for mercury content. In addition, a filet of the imported seabass was submitted by the family for analysis. Mercury levels in these fish samples are shown in Table 2.

Correlation of Mercury Intake with Blood Mercury Levels

According to studies conducted by Clarkson (*8*), the steady-state blood mercury level of a 70-kg adult expressed in micrograms per liter is approximately equal to the daily methylmercury intake expressed in micrograms mercury per day. This estimate is consistent with our case findings since the man in our study had an estimated mercury intake of 45 µg/day and a steady-state blood mercury level of 58 µg/L. The woman in our study had an estimated intake of 30 µg/day and a steady-state blood mercury level of 37 µg/L.

To further test the relationship of the mercury content of the seabass and blood mercury levels in these individuals, the mathematical model developed by Kershaw et al. (*9*) and the fish consumption history provided by this family were used to estimate mercury levels in the seabass. These estimated values were compared to the actual mercury levels detected in the filets. Kershaw's study of the deposition and clearance of methylmercury identified a biological half-life of 52 days and determined that the ratio of hair and blood mercury levels ranged from 265 to 280. It also defined the relationship between the steady-state concentration of methylmercury in blood (*B*, µg/L) and the daily mercury intake (*d*, µg) as:

$$B = d(f/\text{blood volume})(t_{1/2}/\ln 2)$$

where f is the fraction of daily intake deposited in the tissue compartment (5.9%), blood volume is 7% of body weight for adults (8% for children), $t_{1/2}$ is the average biological half-life (52 days), and ln2 is the natural logarithm of 2 (0.693). By applying this formula to the fish consumption and clinical test data for this family, the concentration of mercury in the seabass was estimated to be between 0.4 and 0.8 mg/kg (Table 3), which was similar to the levels detected in two samples of this fish (0.5 and 0.7 mg/kg) providing additional evidence to support the conclusion that the seabass was this family's principal source of mercury exposure.

Biological Half-Life Calculation

The kinetics of mercury excretion and the elimination rate constant k were obtained by plotting the natural logarithm of the ratio of blood mercury levels at days 0, 15, 70, and 200 and steady-state blood mercury concentrations {ln[Hg]/[Hg_0]} versus the time in days (Fig. 1) (*10*). The data points in this figure fall on a straight line indicating that excretion followed first-order kinetics. Elimination rate constants of 1.1–1.2 × 10^{-2} per day were derived for the adults. Using the standard formula $t_{1/2} = \ln 2/k$ (*11*) these rate constants yielded biological half-lives of 58 and 63 days. These half-lives fall within the range of 39 to 67 days that was described by Kershaw et al. (*9*).

Discussion

The family described in this case study was found to have elevated blood and hair mercury levels after they had consumed imported seabass approximately twice a week over a period of several months. The seabass was purchased from a local seafood market and according to the vendor originated in the South American nation of Chile. Two samples of this fish contained mercury levels of 0.5 and 0.7 mg/kg. Most of the mercury is presumed to have been methylated although the analytical methods used in our study did not speciate the mercury. Steady-state blood mercury levels in the family members ranged from 37 to 58 µg/L. Normal blood mercury values range from below detection to 5 µg/L, and levels as low as 10 to 20 µg/L have been associated with memory disturbances, tremors, and impaired hand–eye coordination (*12*).

Current food safety guidelines developed by the FDA allow seafood to contain up to 1 mg/kg mercury as methylmercury (*4*). This guideline was based on a review of data from poisoning incidents that occurred in Minimata and Niigata, Japan, in which no symptoms of toxicity were observed in adults whose blood mercury levels were below 200 µg/L, and also based on a Swedish study by Skerfving (*13*). The Skerfving study associated a steady daily intake of approximately 300 µg mercury as methylmercury by a 70-kg adult with a blood mercury level of approximately 200

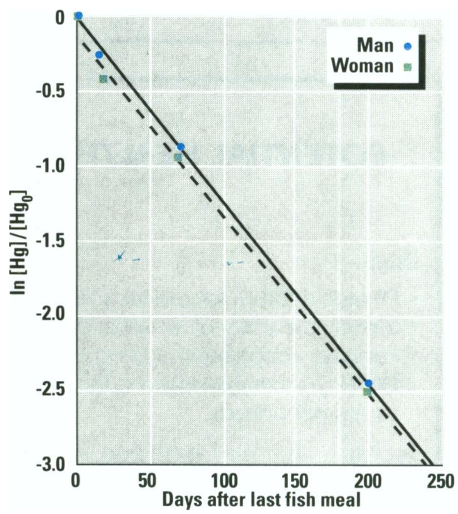

Figure 1. Linear regression of the natural logarithm of the ratio of whole-blood mercury levels at days 0, 15, 70, 200 versus the time in days. For the woman, -slope = k = 0.011, R^2 = 0.99; for the man, -slope = k = 0.012, R^2 = 0.99

μg/L. The agency used an uncertainty factor of 10 to derive an ADI of 30 μg. The FDA assumed that daily ingestion of 30 μg mercury was unlikely since, according to the Tuna Research Foundation (TRF) survey (*14*), the average consumption of all fish among the fish-eating population of the United States was only 18 g/day; and daily consumption of species that contained high methylmercury levels was considerably lower. In their 1986 article, FDA scientists Tollefson and Cordle wrote, "If 11.53 g of swordfish with a mercury level of 1.5 ppm were consumed each day, and this would include over 95% of all swordfish eaters, the daily mercury intake would be 17.3 μg, still below the ADI of 30 μg" (*15*: p. 206).

All three members of the family described in this case study exceeded the average fish consumption rate of participants in the TRF survey. The father consumed an average of 113 g of fish per day—more than 6 times the TRF survey average. His wife and son consumed approximately 75 and 37 g of fish per day. Their estimated mercury intakes ranged from 9 μg/day for the child, to 31 and 52 μg/day for the mother and father, respectively. While no overt clinical symptoms were observed in these individuals, one adult complained of sleep disturbances and concentration difficulties. These symptoms are consistent with the neurotoxic effects of methylmercury exposure. The family was not evaluated for subclinical health effects such as memory and visual disturbances that have been associated with chronic exposure to low levels of methylmercury.

This case study provides support for the methylmercury uptake and excretion models developed by Kershaw et al. (*9*) and Skerfving (*13*). In addition, this case demonstrates the failure of existing food safety regulations that were based on average fish consumption rates and body weights to protect individuals whose dietary habits and body weights fall outside of the normal range. The daily mercury intakes of both adults in this case study exceeded the FDA's ADI for mercury even though none of the fish in their diet exceeded the 1 mg/kg guideline set by that agency. The highest mercury level detected in any of the fish they consumed was 0.7 mg/kg, a level that is not uncommon in sport fish from many Wisconsin lakes or in predatory marine species such as tuna and swordfish. The "1994 Health Guide for People Who Eat Sport Fish from Wisconsin Waters" (*16*) recommends that women of childbearing age not eat fish that contain mercury levels above 0.5 mg/kg. Species listed in this advisory include walleye, northern pike, largemouth bass, and catfish from several inland lakes.

To prevent the public health risks that are posed by methylmercury-contaminated seafood and fish, federal and state agencies may be need to revise existing food safety guidelines. Based on our findings, it may be necessary to lower the concentration of mercury that is permitted in commercial fish to at least 0.5 mg/kg, the level advised for sport fish. It may also be prudent for the FDA to provide consumption frequency advice to commercial fish consumers.

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